UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1060

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C. ▼ May, 1922

SITKA SPRUCE

ITS USES, GROWTH, AND MANAGEMENT

By

N. LEROY CARY, Forest Examiner

CONTENTS

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TWO MAGNIFICENT SPECIMENS OF SPRUCE IN ALASKA.

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SITKA SPRUCE: ITS USES, GROWTH, AND MANAGEMENT.

By N. Leroy Cary, *Forest Examiner.*

CONTENTS.

INTRODUCTION.

Sitka spruce (*Picea sitchensis* (Bong.) Trautv. and Mayer), also called tideland spruce, is an important timber tree of the Pacific coast region, growing naturally from Alaska to northern California. It is found largely at low altitudes and never very far from the ocean. In Alaska it is the principal tree of commerce; in Oregon and Washington it is one of the components of the dense and luxuriant coniferous forest that blankets the humid strip of country on the west side of the coastal ranges. Here several of its associate trees are more abundant than Sitka spruce; but in the superior qualities of its wood, in its magnificent form, and in its immense size it has no superior except the redwood with which it mixes at the south end of its range.

Because Sitka spruce does not ordinarily occur in pure stands, it must be logged in conjunction with other timber species—with Douglas fir, western hemlock, and western red cedar in Washington and Oregon, and with the western hemlock in Alaska. The greater part of the virgin forests in which Sitka spruce occurs has not been

Note.—The writer wishes to acknowledge the valuable assistance given him by Messrs. H. T. Gisborne, R. H. Weidman, and others in the preparation of this manuscript.

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reached by lumbering operations; hence until recently the cut of this timber had been relatively small. It was not well known in the world or national markets until an extraordinary demand for it arose during the war because its wood was found to be superior for airplane construction. Within the space of a few months in 1917 this species, which had been of decidedly secondary importance in the lumber industry, became one of the woods most eagerly sought. To effect an enormous increase in the production of Sitka spruce and to obtain lumber of the quality needed for airplane wing beams, a special organization of the War Department—the Spruce Production Division—was created. The great activity of this organization in promoting the lumbering of this needed Sitka spruce airplane stock in conjunction with the local lumber industry is one of the interesting chapters in the history of the war industries.[1]

Although Sitka spruce may never again be so eagerly sought and so extensively cut as during the war, it has so many superior qualities in the estimation of foresters and lumbermen that it will always play an important rôle in the forest management of the Pacific coast region. It has a habit of rapid growth, makes a large yield per acre, lends itself fairly well to forest management, and produces a wood which has large value for many special purposes, prominent among which is the manufacture of paper.

GEOGRAPHIC DISTRIBUTION AND ALTITUDINAL RANGE.

The botanical range of Sitka spruce, as shown in figure 1, lies along the north Pacific coast, roughly between 40° and 60° of latitude, and in that narrow strip of shore line often described as the fog belt. Its width is nowhere more than 200 miles from the coast line eastward, and usually much less.

In Alaska this species occurs as far north as the west shore of Cook Inlet, the north end of Kodiak Island, and along the Lynn Canal, and is generally abundant southward, on the islands and mainland near the coast of southeastern Alaska. In British Columbia it is found chiefly along the shore line and on the lowlands of the large rivers like the Fraser.

In the United States it is found in the western part of the State of Washington on the lower benches and bottomlands of the rivers along the Pacific coast, and less commonly about Puget Sound, occurring sporadically in the foothills of the Cascade Range. In Oregon it is found under similar conditions but almost exclusively west of the crest of the Coast Range; it extends up the Columbia River only 50 miles from its mouth, and farther south not more than

[1] "History of Spruce Production Division, United States Army," issued by the United States Spruce Production Corporation.

20 miles inland. In California it grows close to the shore line and along the Smith and Klamath Rivers; the southern limit of its range is near Casper, in Mendocino County.

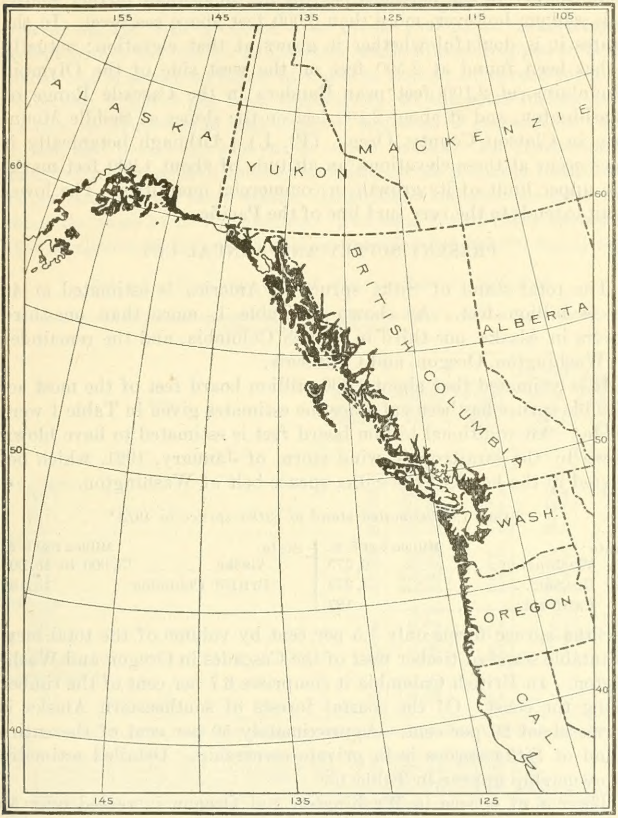


FIG. 1.—Botanical distribution of Sitka spruce, shown by shaded areas.

Heavy commercial stands of this species are found all the way from southeastern Alaska to Coos Bay, Oreg., though by no means does this tree preponderate in the forest growth throughout this strip nor is it even present everywhere. The heaviest stands of Sitka spruce, in its entire range, occur in the northwestern part of the

Olympic Peninsula (Washington) along the Soleduck, Dickey, and Hoko Rivers at elevations between 400 and 600 feet.

The upper altitudinal limit has been noted by many observers as being higher in the northern part of its range than farther south; it is seldom, however, more than 3,000 feet above sea level. In the States it is doubtful whether it grows at that elevation; actually it has been found at 2,500 feet on the west side of the Olympic Mountains, at 2,100 feet near Bandera in the Cascade Range of Washington, and at about 2,100 feet on the slopes of Saddle Mountain in Clatsop County, Oreg. (Pl. I.) Although botanically it does occur at these elevations, an altitude of about 1,200 feet marks the upper limit of its growth in commercial quantities. The lower limit extends to the very surf line of the Pacific.

PRESENT SUPPLY AND ANNUAL CUT.

The total stand of Sitka spruce in America is estimated at 40 to 44 billion feet. As shown in Table 1, more than one-third occurs in Alaska, one-third in British Columbia, and the remainder in Washington, Oregon, and California.

It is estimated that about 1,600 million board feet of the most accessible spruce has been cut since the estimates given in Table 1 were made.[2] An additional billion board feet is estimated to have blown down by the catastrophic wind storm of January, 1921, which occurred in the heart of the Sitka spruce belt of Washington.

TABLE 1.—*Estimated stand of Sitka spruce in 1918.*[3]

State:	Million feet b. m.	State:	Million feet b. m.
Washington	6,575	Alaska	15,000 to 18,000
Oregon	4,374	British Columbia	15,186
California	187		

Sitka spruce forms only 1.5 per cent by volume of the total merchantable stand of timber west of the Cascades in Oregon and Washington. In British Columbia it comprises 6.7 per cent of the timber along the coast. Of the coastal forests of southeastern Alaska it forms about 20 per cent. Approximately 50 per cent of the entire stand of Sitka spruce is in private ownership. Detailed estimates of ownership appear in Table 10.

The cut of spruce in Washington and Oregon increased over 50 per cent in the year 1918, and practically all of this increase was made up of Sitka spruce. The cut of spruce in the United States increased very little, and in general is declining. For a number of

[2] "Supplies and Production of Aircraft Woods," by W. N. Sparhawk, National Advisory Committee for Aeronautics, Fifth Annual Report. Rpt. 67, p. 9, 1919.

[3] Figures for all localities except British Columbia compiled by Forest Service from county records and private, State, and Government estimates. British Columbia figures from "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 330, 1918.

years Maine had been the leading spruce-producing State, cutting chiefly red spruce; but the pressing need for spruce aircraft lumber for war uses stimulated production in the Pacific Northwest to such an extent that in 1918 Washington took first place in the production of spruce with a cut of over 275,000,000 board feet, Oregon second with a cut of over 215,000,000, while Maine dropped to third place. As is shown in detail in Table 2, the cut of spruce for 1918 comprised 6 and 8 per cent, respectively, of the total lumber production in Washington and Oregon, less than 2 per cent in California, and practically the entire cut in Alaska. No distinction is made between species of spruce, but Sitka spruce probably forms over 95 per cent in these three States. In British Columbia the ratio was about the same as in Washington. The total cut of Sitka spruce in 1918, exclusive of British Columbia, exceeded 536,000,000 board feet.

TABLE 2.—*Total reported cut of spruce lumber, 1915–1918.*

[No distinction is made between species of spruce: Sitka spruce probably forms over 95 per cent in Washington, Oregon, and California.]

Year.	Number of active mills reporting.	Quantity of spruce reported cut.	Per cent of total lumber cut.	Per cent of total spruce cut in United States.	Average value per 1,000 feet f. o. b. mill.
		M feet. b. m.			
Washington:					
1915 [1]	49	196,203	5.3	16.4	$14.08
1916 [2]	65	221,295	5.0	19.6	14.08
1917 [3]	66	198,271	4.6	20.3	22.34
1918 [4]	60	275,826	6.0	28.1	23.91
Oregon:					
1915 [1]	20	65,327	4.3	5.5	13.56
1916 [2]	23	96,245	4.3	8.5	11.96
1917 [3]	26	120,647	4.9	12.3	28.28
1918 [4]	35	215,828	8.0	22.0	27.03
California:					
1915 [1]		9,477	0.8		
1916 [2]	2	13,871	0.9	1.2	14.44
1917 [3]	4	20,659	1.5	2.1	17.50
1918 [4]	8	16,663	1.3	1.7	20.75
Alaska: 1918 [5]	18	28,716	98.0		23.00
British Columbia:					
1915 [6]	49	[7] 56,360			13.60
1916 [6]	48	[7] 49,077	5.6		14.66

[1] "Production of Lumber, Lath, and Shingles in 1915 and Lumber in 1914," U. S. Dept. Agr. Bul. 506, p. 20.
[2] "Production of Lumber, Lath, and Shingles in 1916," U. S. Dept. Agr. Bul. 673, p. 21.
[3] "Production of Lumber, Lath, and Shingles in 1917," U. S. Dept. Agr. Bul. 768, p. 21.
[4] "Production of Lumber, Lath, and Shingles in 1918," U. S. Dept. Agr. Bul. 845, p. 24.
[5] "Character and Distribution of the 1918 Lumber and Shingle Cut of Washington, Oregon, and Alaska, by Producing and Consuming Regions," by T. J. Starker, West Coast Lumberman, Vol. 36, No. 423, p. 26, 1919.
[6] "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 178, 1918.
[7] No distinction is made between species of spruce; probably about 80 per cent Sitka spruce.

CHARACTERISTICS OF THE WOOD.

Sitka spruce wood is light, soft, straight-grained, tough, easily worked, and very strong for its weight. It is tasteless and contains very few resin ducts. The color of the heartwood is a pale pinkish brown, which blends imperceptibly into the creamy white of the

sapwood. The longitudinal surface of the wood shows a silky sheen, and the tangential surface, less noticeably, slight indentations or dimples. There is no distinct line of demarkation between the springwood and the summerwood as in Douglas fir.

Compared with other woods of similar weight, Sitka spruce is of greater strength and toughness. Table 17 (Appendix) shows the value of its mechanical properties as measured by laboratory tests. Individual test specimens may show a variation of as much as 16 per cent from the data on bending, compression, shearing, tension, and such properties.

Spiral grain is found in Sitka spruce as in other species, though not to any great extent. During the war specifications for airplane stock required that no spiral-grained wood be accepted which had more than 1 inch departure in 20 inches of length. Tests showed that a greater amount of twist caused a marked reduction in strength for aircraft purposes. Spiral grain in Sitka spruce can generally be detected in the standing tree by a twisting of the fluted portions of the lower trunk.

The calorific power of one cord of air-dried Sitka spruce wood is 52 per cent of that of a short ton of coal, and that of western hemlock and Douglas fir is 58 and 68 per cent, respectively.

USES.

The varied properties of Sitka spruce fit it for a wide variety of uses. It is the premier wood for the manufacture of aircraft. It is unsurpassed for pulp and is especially adapted for musical instruments. It is also a desirable wood for boxes, crates, barrels, veneer, and woodenware.

By far the most extensive use to which the wood is put is the manufacture of lumber. As such, in one form or another, it is used for about the same purposes as the other spruces. About 40 per cent is used for construction and similar purposes without further manufacture. While not suitable for heavy construction, it is well adapted for many building uses in which light weight, ease in working, and ability to take and hold nails and paints are essential. It is especially suitable for large doors, such as are used for garages, freight houses, and similar structures. It is extensively used for beveled siding. As a car stock it is unsurpassed. The bulk of the lumber, however, is remanufactured into a large variety of products.

More than half the lumber cut of this species is consumed by the planing mill, box, and crate industries. It cuts to advantage for doors, window and door frames, and molding. Belonging to the class of tasteless woods, Sitka spruce is extensively used for containers in which articles of food are packed or handled.

Because of its light weight, combined with strength and toughness, Sitka spruce is the most desirable and most generally used wood for such airplane parts as wing beams, struts, longerons, ribs, and plywood parts. Although red, white, and Sitka spruce do not differ greatly in strength properties, the last species, on account of its greater size and consequently its greater proportion of clear lumber, is a more important source of aircraft material than the other two. Because of this and the relatively large supplies of virgin timber still remaining, Sitka spruce will probably for many years be a very important species in the aircraft industry, notwithstanding the fact that the supply is far from the centers of manufacture.

Because of the resonant quality of the wood, its even structure, the absence of vessels, the extremely fine and regularly distributed medullary rays, and the straight and long fibers, spruce generally is considered to be the best wood for piano sounding-boards, as well as for musical instruments generally. Sitka spruce yields a large proportion of clear lumber and wood of selected quality for this purpose, but its rapid growth tends to lessen the resonant quality in comparison with the slower growing eastern species.

The wood is not durable in contact with the soil or when exposed to weather. It is less suitable for piling in salt water than are other species, because of its greater susceptibility to the ravages of the teredo, which may destroy it in one or two years.

For the manufacture of white paper pulp by either the mechanical or the chemical process, spruce is the leading wood used. It is soft, white, and nonresinous, and its fibers are longer, more flexible, and stronger than those of most woods. Containing a maximum percentage of cellulose, it gives a high yield by the chemical process. Although there are several species of spruce, no marked difference is noted in the pulps manufactured from them. A comparison of the character and uses of the pulp made from Sitka spruce with that made from white spruce, a wood that can be considered standard for pulping by the sulphite, sulphate, and mechanical processes, indicates no practical difference.

Because of the long distance to the large paper markets of the East, the utilization of Sitka spruce for paper manufacture is relatively small. Of the domestic spruce consumption in the United States in 1918 for the manufacture of paper, 35,385 cords, or 1.6 per cent, was Sitka spruce from the forests of Washington and Oregon. British Columbia utilizes about half as much Sitka spruce for this purpose as do the States of Oregon and Washington. Other species, including western hemlock, white fir, cottonwood, and Douglas fir, are utilized on the Pacific coast in the manufacture of pulp, but Sitka spruce represents about 15 per cent of the total.

The pulp, paper, and board industry of the West, a long-established one, is confined practically to the Pacific coast, with the pulp mills largely confined to the States of Oregon, Washington, and the province of British Columbia. Alaska has one pulp mill, established in 1921. There is every indication that this industry will grow rapidly in the next few years, with an abundant supply of pulpwood, waterpower, and coal, taken in connection with the fact that the pulp-wood supply in the East is approaching depletion.

LOGGING AND MILLING.

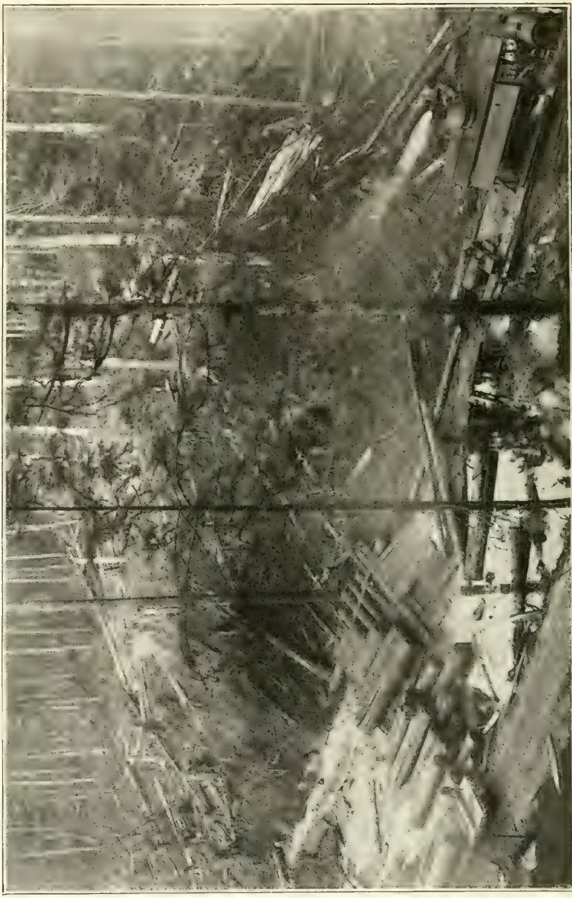
The occurrence of Sitka spruce on the lowlands near tidewater, and along navigable or drivable rivers, on the benches and gently rolling country of the lower foothills makes logging relatively easy, and a mild climate permits year-long operation. As the species occurs largely in association with Douglas fir, hemlock, and cedar, the method of logging is identical with that universally used in the heavy forests of the Pacific coastal region. Here large operations, powerful steam machinery, and heavy capital investments are the distinctive features of logging operations. (Pl. II.) These are required by the large size of the timber, the ground conditions, and the enterprise of the industry.

Trees 6, 8, or 10 feet in diameter, standing on rough steep ground, are felled and converted into logs in such a way that the minimum of waste results; and logs, some of them scaling 10,000 feet and weighing 30 tons, are dragged with great dispatch over the ground or swung down steep slopes and over deep canyons on overhead cables. The greater part of the timber is transported from the woods to the mills or waterside over standard-gauge logging railroads for distances ranging from a few miles to 30 or more. (Pl. III.) To a limited extent motor trucks (Pl. IV) are used in conveying logs, and in some cases in the Grays Harbor and Willapa Harbor regions of Washington logs are transported by driving streams. A large percentage of the cut of Sitka spruce reaches the waterside along the Columbia River and in Puget Sound, Grays Harbor, and Willapa Harbor, where the logs are made into rafts and towed to the mills.

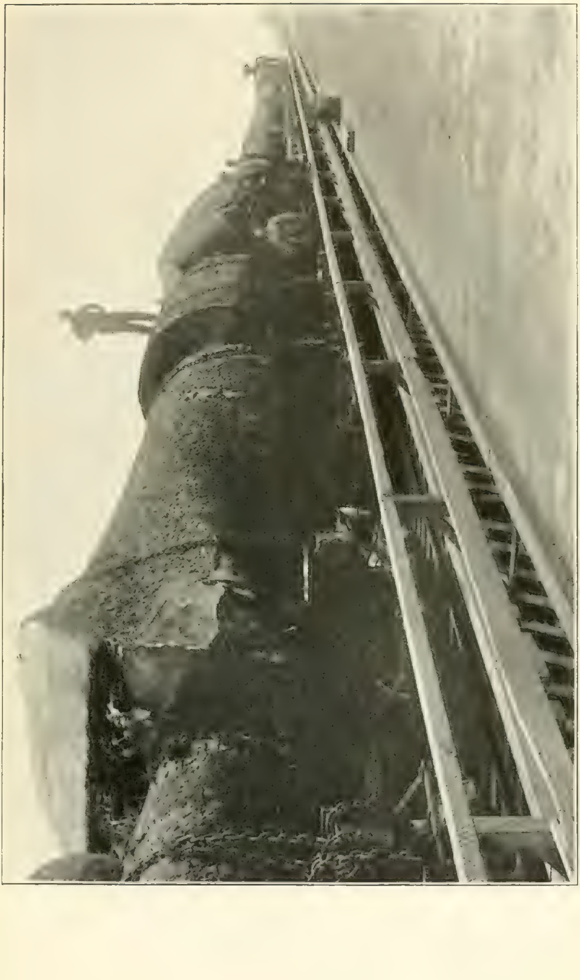
Logging with animals in Oregon and Washington is confined to small operations getting out ties, shingle bolts, piles, and poles. In Alaska, operations are found only along the shore line, and there both hand and machine methods are employed. If the latter method is used the donkey engine is mounted on a float, the hauling line is led inshore a thousand feet or more, and the logs are skidded directly to the water to be towed to the mills.

The sudden and urgent demand in 1917 for high-grade spruce timber for airplane material, which existing logging operations were

GROUP OF SITKA SPRUCES IN CLATSOP COUNTY, OREG.



STEAM LOGGING IN SITKA SPRUCE, SHOWING DONKEY ENGINE AND LANDING.



A TRAINLOAD OF LARGE SITKA SPRUCE LOGS AT BOOMING GROUNDS.

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TRANSPORTATION OF LOGS BY AUTO TRUCK.

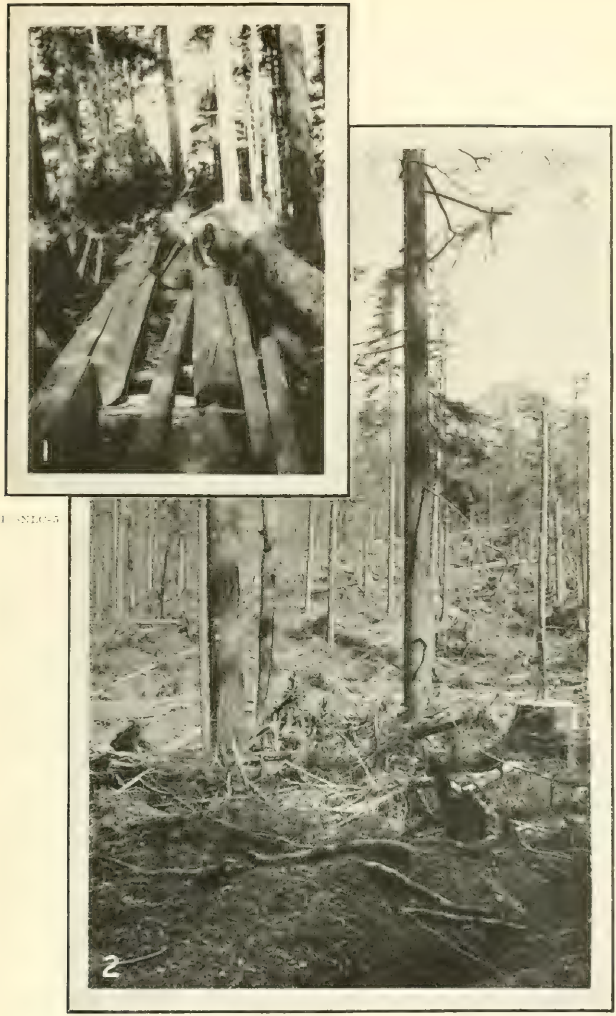

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FIG. 1.—RIVING FOR CLEAR AIRPLANE MATERIAL. FIG. 2.—DÉBRIS AFTER SELECTIVE LOGGING.

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BASAL SWELL IN SITKA SPRUCE IN ALASKA.

unable to meet, caused the Spruce Production Division to encourage small isolated operations to rive out by hand cants of clear spruce from selected trees. By means of wedges and jacks huge logs were split to obtain cants of clear, straight-grained wood, which were dragged from the woods, usually by horses, and sent to resaw plants. (Pl. V, fig. 1). That method of logging was discarded later in favor of a plan of logging selected trees on a larger scale, and this method resulted in a more rapid production of high-grade spruce.[4] In logging selectively an area was combed of all trees which were of airplane quality, and the others were left standing. This method avoided the cutting of low-grade spruce and other timber for which there was no market.

The cost of logging Sitka spruce has varied widely, more particularly during and since the war. Before the war the average cost of logging was about $5.50 per thousand feet; in 1919 it amounted to approximately $11 per thousand feet; and in 1920 it was somewhat higher.

Sitka spruce timber is normally cut into logs ranging from 32 to 40 feet in length. As about 40 per cent of all timber cut on the Pacific coastal region is logged by operators engaged solely in logging, who sell their logs in the open market, logs are graded according to size and quality into No. 1, 2, and 3 logs. It is estimated that Sitka spruce timber as logged will grade: Twenty per cent No. 1 logs, 40 per cent No. 2, and 40 per cent No. 3. Prior to the war Sitka spruce logs sold for about $12, $9, and $6 per thousand for No. 1, 2, and 3 logs, respectively. In 1920 they sold for $30, $24, and $18 on this basis. At the height of war-time operations in 1918 a price of $35 for No. 1 logs was reached.

Most of the Sitka spruce lumber that is manufactured in the United States is cut in the large band sawmills of the Coos Bay district of Oregon and the Grays Harbor and Willapa Bay districts of Washington. The sawmills of Alaska, with a daily capacity of 25,000 to 40,000 board feet of lumber, are smaller comparatively.

The cost of manufacture before the war was a little less than $5.50 per thousand feet; in 1919 it amounted to about $12, and in 1920 it was a little higher.

Although exceedingly high prices were paid in 1918 for clear lumber suitable for aircraft construction, the average wholesale value of mill-run Sitka spruce in that year varied from $20 to $27 per thousand board feet. (See table 2.) Before the war an average price of about $14 obtained. Prices on January 1, 1919, are given in table 3.

[4] "History of Spruce Production Division," 1919.

TABLE 3.—*Range in selling prices of different grades of spruce lumber (f. o. b. mill), January 1, 1919.*

Grade.	Price per 1,000 ft. b. m.
"B" and better, finish, S2S	$35.00 to $62.00
Factory select and better, S2S	35.00 to 62.00
No. 1 shop, S2S	32.00 to 39.00
Shop common, S2S	30.00
No. 2 shop, S2S	27.00 to 34.00
Box, Nos. 1, 2, and 3, S2S	26.00 to 28.00
Common boards, S2S	25.00
Common dimension, S1S1E	17.50 to 30.00

Regarding the prices of Sitka spruce stumpage, it may be said that they varied as greatly in the last few years as did logging and milling costs. Ten years ago average stumpage was worth about $1.50 per thousand feet. Just prior to our entrance into the war it was about $2.75 per thousand feet, and in 1920 it reached $3.50. During 1918 stumpage values of selected trees to be cut in riving or logging operations ran as high as $7.50 per thousand feet. Sitka spruce stumpage, of course, like that of other species, varies in value with topography and accessibility. For this reason values greater than those given here, as well as values considerably less, have obtained.

SIZE, AGE, AND DISTINGUISHING CHARACTERISTICS.

SIZE.

Sitka spruce, which is the largest of the spruces, grows to a size comparable with the maximum for Douglas fir and cedar, and larger than its other associates.

When maximum sizes are considered, individual specimens of Sitka spruce have been found to attain surprisingly large proportions. Total heights of 296, 285, and 282 feet were recorded in the course of the field work for this study for individuals found in the vicinity of Quinault Lake and Beaver, Wash. All these trees were under 300 years of age. Specimens which measured over 9 feet in diameter at a height of 10 feet above ground were found not merely once or twice, but many times, in both Oregon and Washington forests. The largest diameter recorded was of a tree which grew near Beaver, Wash. It measured 16 feet in diameter at breast height, and because of its gradual basal taper was of large volume (Pl. VI, figs. 1 and 2). Necessarily, large diameters and heights mean large volume, and individual trees in Oregon and Washington occasionally have scaled 40,000 board feet in merchantable contents; but the average tree scales about 8,000 board feet. In Alaska single trees have scaled 24,000 board feet of merchantable material.[5]

[5] "Production of Airplane Lumber in Alaska," by W. G. Weigle, Alaska Pioneer, vol. 1, No. 2, p. 4, 1918.

The species attains its maximum development in Washington and Oregon. The average tree found in the virgin forest has a height of about 230 feet and a diameter of 4 feet, measured 15 feet above ground. North of the optimum range in British Columbia it grows to maximum diameters of 8 to 12 feet and heights of 160 to 180 feet; but ordinarily it is only 3 to 6 feet in diameter.[6] In Alaska, too, its average diameter is 3 feet and its height about 150 feet, but single trees frequently exceed this. In California it is smaller than farther north and becomes only a medium-sized tree. This subject is discussed more fully under the heading "Growth."

LONGEVITY.

Sitka spruce is a long-lived tree. Sudworth reports a maximum age of 750 years.[7] During the recent study, however, the oldest tree that could be found was 586 years of age. It is doubtful whether many individuals ever reach an age of over 600 years, and the mean mature age is not more than 450 years.

DISTINGUISHING CHARACTERISTICS.

An outstanding characteristic of the appearance in the forest of Sitka spruce is its bark (Pl. VII). The thin, stiff, cupped, and elliptical dark purple-gray scales 1 or 2 inches in diameter make this species easily distinguishable from its associates in the stand. Little protection is afforded to the living tissues, however, by the bark, which is only one-half to 1 inch thick.

The needles are also of distinctive appearance. In spring the yellowish green color of new needles in sprays that bend downward limply at the ends of the branches stands out in contrast with the dark bluish green of the older needles; and although the young leaves are soft and velvety to the touch, during the remainder of their 5 to 6 year existence they are stiff and stand out straight in all directions around the twig, each needle tip being keenly pointed and quite bristly to the touch. The leaves are somewhat flattened, only indistinctly four-angled, and about 1 inch long.

The cones, too, exhibit peculiarities by which this species may be identified. They have an average length of 3 inches, are light brown in color, elliptical in shape, and hang down conspicuously from the upper branches. The cone scales are thin and papery, with irregular margins but slightly pointed in general outline, and are firmly attached to the central stalk of the cone. Maturity is reached at the end of one year's development; soon thereafter the scales open and release the small dark brown seeds with their large thin wings adhering to them. Most of the cones drop from the

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[6] "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 199, 1918.

[7] "Forest Trees of the Pacific Slope," G. B. Sudworth, p. 83, 1908.

tree soon after the seeds have been scattered by the wind, but some cones may remain on the branches for a number of years.

The root system is characteristically shallow. This is especially true of trees on swampy soils where the roots spread out very close to the surface; but on deep, porous soils they penetrate 4 to 5 feet into the ground and occasionally as far as 12 feet.

Characteristics of form are unimportant, with one exception, for the recognition of this species. In general, the forest-grown trees are tall, with open, conical crowns and long, cylindrical boles. Their bases are very commonly heavily buttressed. Plates VI (fig. 3), VIII, and IX show the importance of this fact when form is considered. Plate IX, figure 2, gives one clue to its cause; the stumps illustrated in this plate were those of only two out of seven fully grown trees that developed on this one windfall. Basal or butt swell is common in this species and especially so in trees which occur on the lowlands. Incidentally, it should be mentioned that this condition in the tree very materially affects any diameter measurements, for the standard practice in all species is to measure diameters at a uniform height of 4½ feet above the ground, and this practice would give very inconsistent results with large Sitka spruces. Further discussion of this point appears under "Diameter growth." The overmature trees present another characteristic, that of stagheadedness. (Pl. VI, fig. 2.) Such broken-topped trees are apt to develop ascending side branches, and these may grow to 14 inches and more in diameter and 50 feet in height. Trees in this condition, as shown by the cedar snags in Plate XIV, may be called bayonet-topped.

OCCURRENCE.

Sitka spruce stands are found on a variety of sites but may be grouped broadly into two classes—the bottomland or lowland, and the slope or highland. The development of the tree, which to a great extent is influenced by the amount of soil moisture, is the chief difference between the two types, and the altitudinal situation is of only minor consideration. The forest may be of pure spruce or of spruce in mixture with other species. These types occur throughout the range of the species, and a third or "upper slope" type might be added for Alaska to include the bodies of scrubby spruce near the upper altitudinal limit of tree growth.

BOTTOMLAND TYPE.

This type is found in the moist situations of river bottoms and benches above the river beds where there is a deep, rich alluvial soil, and where in places the heavy precipitation of the winter and spring months has so saturated the ground that standing water is not un-

common. Here the trees, though large and tall, are characterized by large buttressed bases, limbiness, and comparatively short clear length. On these moist sites the trees make a noticeably rapid and well-sustained diameter growth, especially from 100 to 200 years of age. In this type Sitka spruce occurs also on tidelands and in swamps where there is considerable inundation; but, although it can stand these conditions, it prefers an excess of soil moisture only with good drainage and in general avoids stagnant sites and acid soils. In contrast with the stands on the bottoms and benches, those in swamps are quite frequently pure, but the trees here are shorter and much more limby. Trees which occur on exposed situations along the coast are small and scrubby and unfit for commercial uses.

SLOPE TYPE.

Spruce stands of the slope type are found on the moist but well-drained hills which border the lowlands and which afford all advantages for excellent growth in their rounded ridges and gentle slopes of deep, rich soil. It is not only in the upland country that this type occurs; similar conditions exist on the rolling, sandy land along the coast. The trees on such sites are fine specimens, large and tall, with long, clear length; and, in contrast with those of the bottomland type they seldom develop buttressed bases. (Pl. XI.) The wood is characteristically fine-grained, and this fact is frequently mentioned by lumbermen as a means of distinguishing between trees of the two types. Spruce in these stands is more often pure than in mixture, and this is especially true on the sandy lands which border the ocean. (Pl. XII.)

COMPOSITION AND VOLUME OF STAND.

Pure stands of Sitka spruce are usually not extensive but are apt to be limited to patches of a few acres in contrast with Douglas fir, which occurs pure over great areas. Larger pure forests of spruce are found occasionally, however, 40 or more acres in size in Oregon, Washington, and British Columbia, and even 100 acres in Alaska; but this is the exception rather than the rule.

When Sitka spruce grows in mixture with other species, the most common associate is western hemlock, and large areas of these two species are found in Alaska and in the States as well. Sitka spruce is also associated with Douglas fir, western red cedar, lowland white fir, silver fir, and Pacific yew throughout the range, with Port Orford cedar and redwood only in southern Oregon and California, and with Alaska cedar and mountain hemlock on the upper slopes in British Columbia and Alaska. In the valley bottoms it occurs with such hardwoods as broadleaf maple, black cottonwood, and red alder. (Pl. X.)

The composition of a typical piece of what is distinguished as the "western hemlock-Sitka spruce type" in British Columbia is as follows:[8]

	Per cent.
Western hemlock	38
Sitka spruce	27
Western red cedar	15
Balsam (silver) fir	15
Others (Alaska cedar and cottonwood)	5
	100

A summary of cruises made in 1918 in spruce stands on the west side of the Olympic National Forest in Washington shows the following average composition of the forest:[9]

	Per cent.
Western hemlock	37
Douglas fir	26
Sitka spruce	21
Silver fir	7
Western red cedar	6
Others	3
	100

The mixed forest is usually of even age; infrequently it is of two age classes, and then the hemlock trees are the smaller and younger ones of the stand. An all-aged forest occurs but rarely, and then as an open stand on swampy soils.

An idea of the composition of the stand and the representation of small-sized trees of other species (in the older stands) may be gained from Table 4. This table shows the results of measurements on 12 sample plots in typical stands in Oregon and Washington in which Sitka spruce comprised from 50 to 100 per cent of the volume of the stand.

TABLE 4.—*Number of trees of Sitka spruce and other species per acre for typical stands of various ages.*

Plots.			Living trees per acre.				
			Sitka spruce.		Other species.		
Designation and locality.	Area.	Age.	Under 12 inches.	Over 12 inches.	Under 12 inches.	Over 12 inches.	Total.
	Acres.	*Years.*					
Newport III	0.4	27	448.0	122.0	30.0	0.0	600.0
Blodgett I	.2	60	104.0	112.0	24.0	32.0	272.0
Raymond I	4.0	70	1.5	27.7	25.2	98.0	152.4
Newport I	2.0	130	2.5	61.0	3.0	8.0	74.5
Tsiltcoos II	2.0	175	1.5	49.5	10.0	13.5	74.5
Raymond II	4.0	175	3.5	13.2	13.8	41.2	71.7
Hoquiam I	4.0	240	.0	18.0	28.2	18.8	65.0
Beaver I	4.0	260	.2	18.2	5.3	9.6	33.3
Tsiltcoos I	4.0	290	.5	21.5	8.0	8.0	38.0
Clatsop I	5.2	310	.0	10.1	.0	10.3	20.4
Newport II	2.0	320	3.0	7.0	43.5	54.0	107.5
Hoquiam II	2.0	340	.0	7.0	40.0	34.0	81.0

[8] "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 61, 1918.

[9] "Descriptive Report of Olympic West Side Spruce," by C. J. Conover. Forest Service manuscript report, p. 13, 1918.

The underbrush, which in both the pure and mixed forests is extremely large and dense, is composed of salmonberry, huckleberry, vine maple, salal, devil's club, elderberry, and cascara, with a preponderance of the first two species. The ground cover consists chiefly of braken, sword ferns, and moss.

The volume of spruce per acre in the virgin stand varies greatly with the proportion of species, the density of stocking, and the quality of the site. The heaviest yields are naturally produced in properly stocked stands on sites where the best growth of individual trees is made. County cruise estimates indicate that the stand of merchantable timber in what would be classed as spruce type (running all the way from 25 per cent to 65 per cent of spruce) varies from 20,000 to 100,000 feet per acre over large areas. Very much heavier, as well as lighter, stands occur in the virgin woods.

CLIMATIC AND SOIL REQUIREMENTS.

Sitka spruce is very exacting in its soil and atmospheric moisture requirements. An abundance of rainfall, frequent fogs, and temperatures moderated by proximity to the sea are the climatic characteristics of the north Pacific coastal strip where this species grows. The yearly precipitation is 75 to 150 inches or more and comes chiefly in the form of rain, well distributed throughout the year, except for about two months in midsummer. Cloudy or partly cloudy days are frequent, and weather records show an average of 240 such days in a single year at one station in the heart of the spruce region. The temperature of the region is generally mild, the annual mean ranging from 38° F. in Alaska to 53° in northern California. Extreme temperatures of 15° below zero in Alaska and 102° above in California are encountered within the range of the tree; but withal it may very readily be seen that Sitka spruce occurs only on areas that offer climatic advantages favorable for growth.

Its soil requirements, however, are not so distinctly defined, and thin, rocky soils on the slopes, pure sand along the coast, and deep, rich alluvial deposits of rivers share equally, under similar conditions of climate, in the distribution of the species; but the trees are larger and reach better development on bottom lands of moist, friable, sandy loam. It is noteworthy that in Alaska the heaviest stands of spruce and those of best quality are found on limestone soils, perhaps partly because these are the deepest and most completely decomposed. Though this species demands a very great amount of soil moisture and can grow on swampy sites, it attains its best development on soils of good drainage.

LIGHT REQUIREMENTS.

Sitka spruce, unlike other spruce, is somewhat intolerant of shade. Compared with its associates, it is less tolerant than western hemlock and western red cedar and about as tolerant as Douglas fir. Seedlings can endure heavy shade and on old burns and logged-over areas establish themselves with little difficulty under the dense cover of deciduous brush, such as salmonberry and huckleberry, and of other coniferous seedling growth; but strangely enough Sitka spruce is seldom found under the heavy canopy of a mature stand. Here temperature, not tolerance, is thought to be the governing factor, and the coolness in the mature stands prevents, whereas the warmth in the openings permits, the germination and establishment of spruce seedlings. As the tree advances in age it demands overhead light, and dies if long overtopped.

The dead side branches, which are often moss-covered stubs 2 or 3 feet long and characteristically coarse and stiff, are very persistent in young spruce. The shedding of the dead limbs and cleaning of the bole starts when the trees are about 50 years old and often is not completed for a century or more. (Pl. XII and Pl. XIII (fig. 1.))

REPRODUCTION.

SEED PRODUCTION AND DISSEMINATION.

Sitka spruce is a prolific seeder. Open-grown trees commence to bear seed at 35 years of age, and trees of all sites are vigorous producers of seed until maturity. Some seed is produced each year and heavy crops are yielded every three or four years. The cones mature in the early fall of the first year and, under normal conditions, open and release the seed within a short period afterwards. A mature tree with a full crown may produce, in a good seed year, 4 to 6 bushels of cones, which yield from 0.65 [10] to 1.25 [11] pounds of clean seed. A pound of these seeds will number between 200,000 and 300,000. Because of their small size and relatively large wings they are often carried by the wind 400 feet or more from the base of the tree. Many of the seeds filter into the deep duff of the forest floor and are stored, their hard covering keeping them viable for several years. The seed has a high percentage of germination. In tests [12] of fresh commercial seed under greenhouse conditions, this amounts to 72 per cent, and is higher than the germination percentage of western hemlock, western red cedar, and Douglas fir as determined in similar tests.

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[10] "Sitka Spruce in Alaska," by B. E. Hoffman. Forest Service manuscript report, p. 9 1912.

[11] "Reforestation on the National Forests," by C. R. Tillotson. U. S. Dept. Agr. Bull. 475, p. 17, 1917.

[12] "Seeding and Planting," by J. W. Toumey, p. 122, 1916.

F—150849

FIG. 1.—VARIATION IN BASAL SWELL, ILLUSTRATED BY TREES IN LEFT AND RIGHT FOREGROUND.

F—150850

FIG. 2.—STUMPS OF MATURE TREES WHICH STARTED ON OLD WINDFALL.

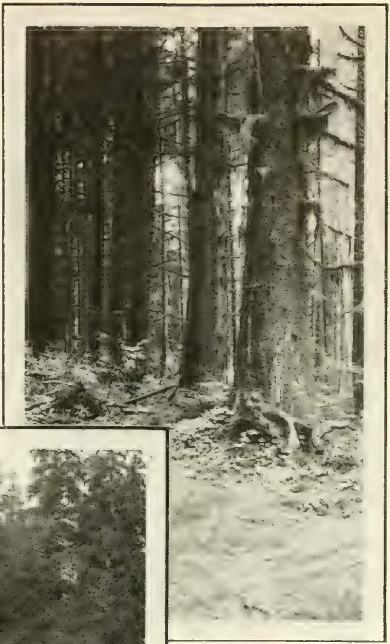
F—NLC-9

SITKA SPRUCE IN MIXTURE WITH RED ALDER AND BROADLEAF MAPLE ON RIVER BOTTOM.

HIGHLAND SPRUCE AT 1,100 FEET ELEVATION IN CLATSOP COUNTY, OREG.

F 150834

PURE, EVEN-AGED STAND OF SITKA SPRUCE (175 YEARS) NEAR TSILTCOOS LAKE, OREG.



F—NLC–11

FIG. 1.—A STAND OF 65-YEAR-OLD SPRUCE WITH UNCLEANED BOLES.

F—NLC–12

FIG. 2.—THRIFTY 18-YEAR-OLD SITKA SPRUCE IN OLD CLEARING.

DENSE REPRODUCTION OF SITKA SPRUCE, CEDAR, AND HEMLOCK ON QUINAULT BURN IN WASHINGTON.

1—NLC 11

FULLY STOCKED SECOND-GROWTH STAND OF 27-YEAR-OLD SITKA SPRUCE.

FIG. 1. FRUITING BODIES OF FOMES PINICOLA.

FIG. 2.—FRUITING BODIES OF TRAMETES PINI.

ESTABLISHMENT OF SEEDLINGS.

Sitka spruce germinates slowly, and in this habit it is similar to other low-altitude species of the coastal region, and in contrast with Engelmann spruce and high-altitude Douglas fir, which require only a short time for germination. Similarly, Sitka spruce seedlings do not respond quickly to atmospheric warmth early in the spring, and their buds do not unfold until the season is well advanced. Were it not for this characteristic much injury to reproduction would result, for during early spring clear, warm weather in the lowlands is often followed by killing frosts.

Moisture, light, and heat are all essential for the germination and establishment of spruce seedlings; but, as moisture is abundantly supplied by rains and fogs in the region, and as the young seedlings are capable of enduring dense shade, heat is the uncertain factor. In this regard the warm exposures of old burns, clearings, and logged-over lands offer conditions more suitable for growth than elsewhere, and, as spruce can compete successfully with all other species, it establishes itself with little difficulty on these sites. In the choice of seed bed, Sitka spruce prefers loose mineral soil, but it can thrive equally well in the decayed wood of down logs and in the deep humus of the forest floor. Plate IX, figure 2, illustrates the establishment of two spruce trees on an old windfall. Because of its extreme tolerance in early youth, Sitka spruce sometimes occurs on fresh earth slides, under a temporary cover type of alder, and eventually becomes the predominating species.

Stands of reproduction in the spruce type are densely stocked. (Pls. XIV and XV.) Counts were made during the recent field study on 10 square-rod quadrates in areas of reproduction, and these counts showed that in thrifty stands under 10 years old there were 3,000 seedlings per acre, and that in stands 30 years old there were 500 trees per acre. Nearly one-quarter of the 30-year-old trees were 12 inches and over in diameter at breastheight. It was also shown that a stand of maximum density, which was 5 years old, contained 35,000 seedlings per acre. In each of these stands 50 per cent or more was spruce, and the remainder was mostly hemlock, with a few cedar and Douglas fir trees. In very dense stands Sitka spruce seedlings generally comprise only 10 to 20 per cent, but this percentage often increases as the stands become older. Under ordinary circumstances spruce is able to maintain itself and even increase notwithstanding the competition of other species. These seedlings, which are rather delicate and slender stemmed during the first few years, later develop heavy, stiff stems. They at first average nearly one-half foot in height growth per year and beyond 15 years of age increase in height at the rate of 3 feet per year.

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CAUSES OF INJURY.

FUNGI.[13]

Sitka spruce, in common with other forest trees, is attacked by two broad groups of fungi—first, those reducing the annual increment; and, second, those reducing the merchantable timber.

In the first group there are two rust fungi. One of these is a broom-forming rust (*Peridermium coloradense*). The mycelium of the fungus is perennial in the twigs of the host, causing pronounced witches' brooms. As a rule, this fungus is not serious, but it may completely dwarf and deform small trees.

The other rust fungus (*Peridermium decolorans*) does not cause any deformation of the host. The mycelium confines itself to the infected needles and does not enter the twigs or branches. The parasite is usually confined to small trees of the sapling and small-pole sizes.

Another needle disease of importance is characterized by a browning of the individual needles. This fungus is *Lophodermium macrosporum* or a closely related species. Infected needles are invariably killed and drop off, but the degree of infection varies. Sometimes only occasional needles are diseased; at other times most of them may be killed. The disease usually attacks the lower branches of young trees. It has been reported as very prevalent along the lower Columbia River in Clatsop County, Oreg.

It is impossible to give an estimate of the amount of damage caused by the needle and twig diseases just mentioned. It is obvious that there must be a greater or less reduction in annual increment of the infected trees, but no exact data are available. Control measures need not be discussed, as present economic conditions preclude such work, except for nursery stock or trees of high aesthetic value.

By far the most important fungi are those which reduce the merchantable volume by attacking and destroying the heartwood of living trees.

The most serious of these on Sitka spruce is the ring-scale fungus (*Trametes pini*) which causes the common red rot or conk rot in the heartwood of living trees. In spruce the attack may be made at any point along the bole. In the split section the decayed wood has a reddish color in its early stages, and later small white sunken spots are found separated by apparently sound reddish wood. The fungus gains entrance to the heartwood of the trees principally through old branch stubs and is exceedingly destructive in mature and overmature stands. Plates XVI (fig. 2) and XVII are illustrations of this fungus.

Next in importance is the velvet-top fungus (*Polyporus schweinitzii*), which causes a pronounced butt rot. The sporophores ap-

[13] Prepared in collaboration with Dr. J. S. Boyce, Pathologist, Bureau of Plant Industry.

pear at the base of the tree, on the trunk in old wounds, or on the ground, coming up from decayed roots. Those on the ground have a short, thick stalk. The disease spreads both by spores blown about in the air and through the ground by means of the decayed roots. The decay which is confined to the heartwood is light reddish brown in the early stages, and pronouncedly cubical, reddish brown, crumbling to a fine powder between the fingers, and often with thin resinous crusts of mycelium in the typical stage. The rot is found in the roots and butt, and rarely extends beyond the first log. Besides the actual loss due to the volume of wood rendered unmerchantable by decay, the infected tree is frequently broken off at the base as a result of the weakening of the roots. Many large overmature trees, completely rotted at the base except for a thin layer of sapwood, are found broken off between 5 and 20 feet above ground, and their loss can be charged directly to the destructive work of this fungus.

The red-belt fungus (*Fomes pinicola*) is of equal importance with *Polyporus schweinitzii* as a butt rot in living trees; but it is also common on dead snags, old windfalls, stumps, and other débris, and thus functions as a beneficial scavenger in the forest. The fruiting bodies are usually found at the base of the tree in the flare of the roots or at scars along the lower portion of the trunk. The typical decay is light reddish-brown in color, somewhat cubical, crumbly and brittle, with white feltlike layers of mycelium occupying the cracks. Infection caused by this fungus is illustrated in Plate XVI, figure 1.

One of the most common fungi found on fallen Sitka spruce, besides the red-belt fungus, is the lacquer-top fungus (*Ganoderma oregonense*), readily recognized by the shiny, lacquerlike, reddish upper surface of the annual fruiting body. This organism has not been reported on a living spruce, but is often found on its associate, the hemlock. There are a number of other fungi of less importance which live on fallen trunks, but do not attack living trees.

Sitka spruce is much freer from decay than either western hemlock or Douglas fir, but snags and down timber decay very rapidly. The earliest infection appears in trees between 60 and 100 years of age; only a slight amount of rot is found in stands between 150 and 300 years of age, and this is confined to the butts of trees. Over 300 years, or after maturity, however, the tops commonly break off, and top rot as well as butt rot is very prevalent, becoming more marked with age. It is not unusual, however, to find trees of 400 years entirely sound at the butt and with very little decay along the trunk or in the top. In general, this species is remarkably free from decay up to 200 years of age.

The amount of resin which the wood of a tree contains, or that it is able to produce to cover any injury, affects its ability to ward off disease. Spruce, which has very little resin, is almost never able

to heal over scars or wounds along the bole; here the spores of fungi soon establish themselves and, on account of the very moist conditions in spruce stands, cause the rapid decay of much sound wood.

Advance rot spreads quickly in this species, and, though often hard to detect, it becomes very noticeable after lumber is dried. It is commonly, though not always, accompanied by a change of color in the wood, appearing as streaks of red, yellow, or green. Tests were made recently by pathologists to show the effect of different stages of decay on the strength of the wood, particularly for spruce airplane stock, but these data are not yet available for publication.

INSECTS.[14]

Although Sitka spruce, like other forest trees, is subject to insect attacks, it is not so susceptible as most of its associates in the forests of the Pacific coastal region. The attacks are naturally more serious in pure or nearly pure stands of Sitka spruce than in stands in which it occurs in mixture. Damage is caused by three classes of insects—bark beetles, defoliators, and borers. The first two classes attack standing timber and the last works in felled trees.

The most important insect enemies of Sitka spruce are the bark beetles, of which the most destructive is the Sitka spruce beetle (*Dendroctonus obesus*). This beetle attacks the living trees and kills them by girdling in the cabium layer. In attacking the trees the first broods enter the inner bark of the middle trunk, and those which appear later extend the infestation to the base of the trunk and even to the larger roots. This beetle also works in the inner bark of stumps, logs, and slash of felled trees. Although no extensive depredations of the Sitka spruce beetle have been found thus far, it has been reported now and then that groups of Sitka spruce have been killed by its activity. If infestations should ever become widespread it would be possible to practice control operations by cutting and barking the infested trees before the beetles emerge in the late spring. It would not be necessary to burn the bark in this work.[15]

From time to time Sitka spruce is subject to the attacks of such defoliators as caterpillars, sawfly larvæ, and aphids, all of which destroy the needles and may therefore occasionally kill trees over large areas. In Clatsop County, Oreg., in 1890 and 1891, Sitka spruce and western hemlock were attacked and killed over an area of thousands of acres by a caterpillar belonging to the Geometrid family. During the years 1917 to 1920 the Sitka spruce and western hemlock on several hundred thousand acres on the Tongass National

[14] Prepared in collaboration with Forest Examiner A. J. Jaenicke, U. S. Forest Service.

[15] For detailed information regarding control measures, see Bulletin 83, Part I, "Bark Beetles of the Genus Dendroctonus," by A. D. Hopkins, Bureau of Entomology, U. S. Department of Agriculture.

Forest in southeastern Alaska were defoliated by the combined activity of sawfly larvæ and caterpillars belonging to the Tineid family. Thus far only a small portion of the Sitka spruce in southeastern Alaska has been killed by this widespread defoliation.

Occasionally aphids kill the foliage of Sitka spruce. The western spruce gall louse (*Aphis abietina*) is believed by Dr. A. D. Hopkins of the Bureau of Entomology to be the aphid which caused the loss of the needles of Sitka spruce over thousands of acres of forest in 1918 in various portions of the coast region in Oregon and Washington. Fortunately the activity of this aphid was of extremely short duration, and only about 15 per cent of the infested spruce was killed. Most of this loss was confined to swamp and tideland areas in the lower Columbia River basin and the coast region and included only the poorer stands of timber. The Sitka spruce gall aphid (*Chermes cooleyi*) is found very commonly doing injury to Sitka spruce reproduction and occasionally causing its death. Large trees also are attacked, but the injury to them is rarely severe. These minute insects cause the development of conelike galls which kill the affected twigs. Infested trees of special value, such as those in parks and streets, may often, with good results, be sprayed with contact sprays like kerosene emulsion.

Fortunately the work of defoliators does not continue more than a few years when it is controlled by natural agencies. Under forest conditions control measures against this class of insects are not feasible. However, defoliators greatly increase the fire hazard on the areas on which they have been active. Nearly always the fires which followed the defoliators did more damage than the insects themselves. The reduction of the fire risk on the defoliated areas is, therefore, an important consideration in defoliator problems.

Felled timber of Sitka spruce is subject to the attacks of various wood borers. Logs cut between April and September are frequently attacked, shortly after being felled, by ambrosia beetles, sometimes called timber beetles or pinhole borers. These are small, elongate, wood-boring beetles which excavate round black tunnels, the diameter of a pencil lead, into the wood of dying trees and stumps, as well as logs. Investigations by the Bureau of Entomology in 1919 showed that species of Gnathothrichus and Xyloterus commonly attack Sitka spruce logs, as well as western hemlock and Douglas fir. These borers may penetrate the wood to a depth of from 4 to 6 inches and therefore seriously reduce the value of the sapwood, especially when Sitka spruce is being used for such special purposes as airplane stock. The logs which are cut in the late fall and winter are usually attacked in the following spring. Logs cut in the early fall are not entered that season; and, if piled loosely in

the open, they often dry sufficiently to be protected from attack the following spring. Logs placed in water are safe from further injury. Damage by these borers can be prevented almost entirely by removing the logs from the woods or placing them in water as soon as they are cut.

Larger wood borers are an important factor in the deterioration of the sapwood and heartwood of fire-killed trees and logs. During the first two summers after the death of the trees or the felling of the trees the borers are most active, and at the end of the two-year period the salvage value is usually next to nothing. If the logs are placed in water or barked within a few weeks after cutting, losses by these borers may be avoided. Logs which are loosely piled in the open soon after cutting usually escape damage because of the rapid drying out of the thin bark, which is then unattractive to the borers for the laying of eggs. Dr. J. M. Swaine, of the Canadian Entomological Branch, recommends covering the logs thickly with brush. The logs to be covered should be piled on skidways and given a very thick covering of green limbs so that the sunlight can not penetrate at all to the logs beneath.

WIND.

Sitka spruce, because of its characteristically shallow root system, can not withstand severe winds. Trees which grow on exposed situations along the coast where they encounter severe winds are windfirm, but they are also scrubby and of little use for lumber. In the virgin forests under normal conditions only the very diseased trees are likely to be windthrown, but in cut-over areas trees isolated by logging and those which border on fresh cuttings are invariably windthrown. (Pl. XVIII.) Spruce trees which have grown in dense stands never become wind-resistant, and full consideration must be given this fact before a method of cutting and a management policy are adopted for a spruce forest.

The hurricane that swept the western edge of the Olympic peninsula, Washington, in January, 1921, felled from 5 to 95 per cent of the timber on a swath 60 miles long and 20 miles wide in the heart of the spruce belt. Six billion feet or more of virgin western hemlock, Sitka spruce, Douglas fir, silver fir, and western red cedar timber was laid flat by the wind. Perhaps a billion feet of Sitka spruce in the State of Washington was windthrown in that storm. All species suffered alike regardless of their relative windfirmness.

In addition to windthrow, other damage from the elements is wrought upon spruce timber by breakage and wind-shake. The breakage consists in the shattering of the tops of overmature and decadent trees, and this permits the entrance of fungous growth,

which spreads quickly through the sound wood and renders much of the upper trunk unmerchantable. Damage from this cause is very common in trees over 300 years of age. Wind-shake is a mechanical defect resulting from heavy stresses in the butt section which are caused by the action of severe winds, and is of infrequent occurrence in large trees. This circular or radial rupture of the wood considerably reduces the value of the tree for lumber.

BURLS.

Another injury is the formation of huge burls along the trunks. This defect has been found abundantly in a limited area in Oregon. The illustrations in Plate XIX are typical examples of the defect. Its cause is uncertain, though probably analogous to similar malformations in many other species.

FIRE.

Sitka spruce is fortunate in having as its habitat a region in which there is less forest-fire hazard than in most parts of the coniferous forest regions of western North America. Frequent rains throughout the year in southeastern Alaska make fires in the virgin spruce woods there quite uncommon; farther south in Washington and Oregon there is more danger of forest fires in the short dry season. Fires in this region are apt to run in the crowns of the trees, and they do so even in the spring months when the surface litter is still too wet to burn. The moss that hangs on the branches of the hemlock, spruce, and fir trees is very inflammable and helps to carry fire. The spruce region of Oregon suffered from several very disastrous and widespread fires a few decades ago, as the "burns" of the Coast Range witness.

Sitka spruce is very susceptible to fire. This is due chiefly to its thin bark, which at stump height is only a half-inch to an inch thick. Fire-scars are uncommon in Sitka spruce, for even a very light surface fire is sufficient to kill the cambium, and the trees, thus girdled, die.

Although an individual tree of Sitka spruce is more susceptible to injury than a Douglas fir of the same size, the forest in which it grows along the coast is less subject to fire than the forest farther inland where Douglas fir predominates. Even though the danger of uncontrollable fires is less in the Coast Range than in the Cascade Range, careful fire protection in both regions is imperative.

GROWTH.

Sitka spruce is one of the most rapid-growing coniferous species in the Pacific Northwest. In keeping with the character of spruces in general, its growth during the first few years is less than that of

many other conifers; but thereafter it increases in size with great rapidity and maintains a fast growth until late in life. Its rate of growth naturally varies with the quality and the character of stand. Moisture conditions are an important factor and growth is more rapid on wet bottomland situations than on the drier slopes. The growth of Sitka spruce varies also in different parts of its range, and is more rapid in Oregon, Washington, and British Columbia than either farther south or north. Average figures on height, diameter, and volume growth are given in the tables that follow, but it is realized that these are not universally applicable. In the appendix will be found tables of growth from several different localities.

HEIGHT.

In the seedling stage the height growth of Sitka spruce is fairly rapid, but not so fast at this period as that of its associates, Douglas fir, western hemlock, and western red cedar. Table 5 shows the height growth of dominant, open-grown Sitka spruce seedlings, and is compiled from measurements taken of young trees which grew in seven different localities and sites in Oregon and Washington. Here the reproduction was sometimes found in pure stands, but more often in mixture with other species.

TABLE 5.—*Height of dominant, open-grown Sitka spruce seedlings, averaged for all sites in Oregon and Washington.*

[Based on 2,102 sectional measurements of 322 trees.]

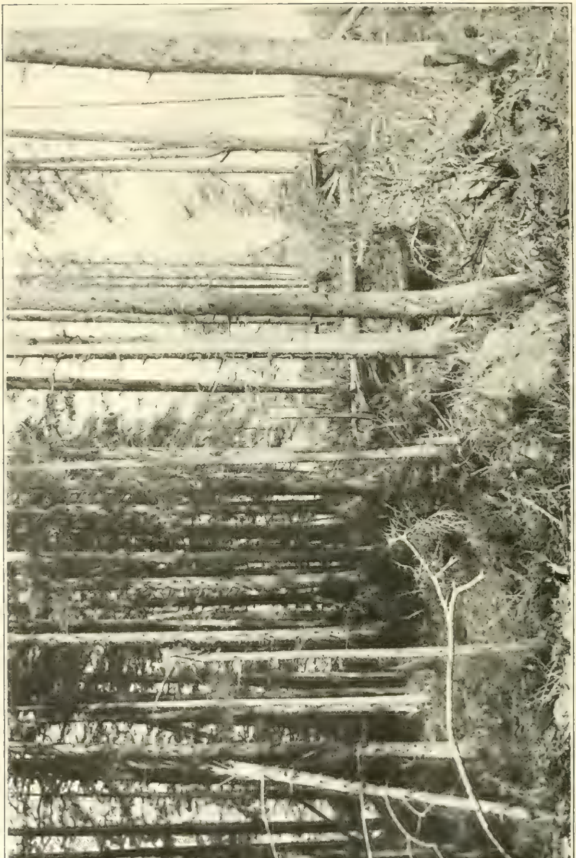
(Curved.)

Age.	Height.	Current annual growth.	Age.	Height.	Current annual growth.
Years.	*Feet.*	*Feet.*	*Years.*	*Feet.*	*Feet.*
1	0.2	0.2	10	6.6	1.2
2	.5	.3	11	8.0	1.4
3	1.0	.5	12	9.8	1.8
4	1.6	.6	13	12.0	2.2
5	2.2	.6	14	14.4	2.6
6	2.8	.6	15	17.2	2.8
7	3.5	.7	16	20.2	3.0
8	4.4	.9	17	23.4	3.2
9	5.4	1.0			

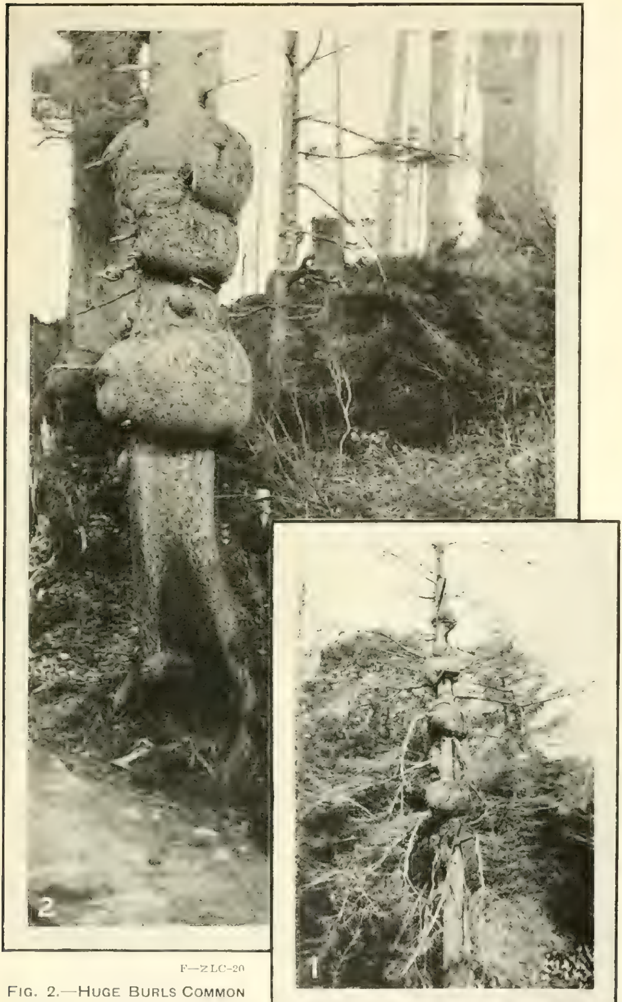
After the early years, growth increases rapidly and is maintained at a good rate until late in life. In the sapling stage a growth of 3 feet and over a year is not unusual. At the age of 50 the average dominant tree is still growing 1.7 feet per year, and at 100 years as much as 1 foot. At these ages the height growth of spruce compares very favorably with that of Douglas fir. This comparison is made from the available growth tables for the species mentioned, under conditions representative for each species, and not by comparison of the several species growing side by side on the same site.

F—NLC-17

END VIEW OF SPRUCE LOG INFECTED WITH TRAMETES PINI.



HEAVY WINDFALL DAMAGE AT EDGE OF CUTTING IN 175-YEAR-OLD STAND NEAR TSILTCOOS LAKE, OREG.



F—ZLC-20

FIG. 2.—HUGE BURLS COMMON ALONG THE COAST NEAR NEWPORT, OREG.

F—NLC-19

FIG. 1.—ABNORMAL GROWTH IN SPRUCE.

F—NLC 21

END SECTION OF SITKA SPRUCE LOG, SHOWING SUSTAINED DIAMETER GROWTH.

The figures given in Table 6 indicate the average total height and average annual height growth in each decade of older spruce of various ages, averaged from the measurement of 554 dominant trees. The figures are dependable for trees up to 300 years; beyond that age reliable height-growth figures are difficult to obtain, because very old spruce trees are commonly stag-headed.

TABLE 6.—*Average total height at various ages, and average annual height growth in each decade of Sitka spruce on all sites in Oregon and Washington.*

[Based on 1,260 sectional measurements of 554 dominant trees.] (Curved.)

Age.	Average total height.	Average annual height growth in each decade.	Age.	Average total height.	Average annual height growth in each decade.
Years.	*Feet.*	*Feet.*	*Years.*	*Feet.*	*Feet.*
20	31	2.4	220	224	0.3
30	51	2.0	230	226	.2
40	70	1.9	240	228	.2
50	87	1.7	250	230	.2
60	104	1.7	260	232	.2
70	119	1.5	270	233	.1
80	132	1.3	280	234	.1
90	144	1.2	290	235	.1
100	154	1.0	300	236	.1
110	164	1.0	310	236	.1—
120	173	.9	320	236	.1—
130	181	.8	330	237	.1—
140	188	.7	340	237	.1—
150	194	.6	350	237	.1—
160	200	.6	360	237	.1—
170	205	.5	370	237	.1—
180	210	.5	380	238	.1—
190	214	.4	390	238	.1—
200	218	.4	400	238	.1—
210	221	.3			

DIAMETER.

Diameter growth in this species is remarkably rapid and well sustained, as the figures in Table 7 indicate. In this table the figures represent the average of measurements taken of 557 dominant trees from seven localities in Oregon and Washington. Although its annual rate of diameter growth culminates at about the age of 40 years, it maintains a growth of over 3 inches per decade up to about 60 years, and thereafter for a few decades over 2 inches per decade. At the advanced age of 400 years, the data in Table 7 indicate, the diameter is still increasing at the rate of over 1 inch per decade. Exceptionally rapid diameter growth is attained on wet sites, where sometimes it may amount to three-quarters and even 1 inch annually during early years of vigorous growth. Plate XX shows the diameter growth of Sitka spruce.

TABLE 7.—*Average diameter outside bark at 15 feet above ground at various ages and average annual diameter growth in each decade of Sitka spruce growing on all sites in Oregon and Washington.*

[Based on measurement of 557 dominant trees.] (Curved.)

Age.	Average diameter.	Average annual diameter growth in each decade.	Age.	Average diameter.	Average annual diameter growth in each decade.
Years.	*Inches.*	*Inches.*	*Years.*	*Inches.*	*Inches.*
20	2.0		220	43.4	0.14
30	5.6	0.36	230	44.8	.14
40	9.5	.39	240	46.2	.14
50	12.8	.33	250	47.5	.13
60	15.7	.29	260	48.8	.13
70	18.2	.25	270	50.1	.13
80	20.5	.23	280	51.4	.13
90	22.5	.20	290	52.7	.13
100	24.4	.19	300	54.0	.13
110	26.3	.19	310	55.3	.13
120	28.1	.18	320	56.6	.13
130	29.9	.18	330	57.8	.12
140	31.5	.16	340	59.0	.12
150	33.1	.16	350	60.2	.12
160	34.7	.16	360	61.4	.12
170	36.2	.15	370	62.5	.11
180	37.7	.15	380	63.6	.11
190	39.2	.15	390	64.7	.11
200	40.6	.14	400	65.8	.11
210	42.0	.14			

Diameter measurements at breast height are of little value in a Sitka spruce growth study, as this species commonly has a pronounced basal swell and its root base is usually well above the general ground level, owing to its habit of starting on down logs. For these reasons, in Forest Service timber survey work in spruce, diameters are taken at a point 1 foot above the swell; but this is a variable height and can not be used in growth studies when the relation between age and diameter is desired. In Table 7, therefore, diameters are given for a distance 15 feet above the ground and on most trees this point is above the basal swell. It must be borne in mind, however, that this uniform height above ground does not mean a uniform distance between this point and the root bases of all the trees measured. Trees which started on fallen logs 4 or 5 feet in diameter naturally have their root bases 4 or 5 feet above the ground, and the number of annual rings showing at the 15-foot point in these trees is, of course, less than at this point on trees whose root bases rest on the ground. It was found, however, that the discrepancy for all the trees measured amounted to only two years. This variation is rendered of little consequence by the rapid height growth of Sitka spruce in its sapling stage, when 3 feet per year is not an unusual growth. Another point that must be kept in mind in this connection is that it takes an average of 14 years for the seedling to reach a height of 15 feet, as shown by Table 5, and therefore a tree must be more than 14 years old before it shows diameter at this point of measurement.

VOLUME.

The volume growth of Sitka spruce is also rapid and well sustained. Table 8 indicates the average diameter, height, and volume, and the average volume growth that may be expected of dominant Sitka spruce trees in the spruce region of Oregon and Washington. The figures for diameter, height, and board-foot volume were taken from Tables 6, 7, and 11. Those for cubic-foot volume were supplied from a tree diagram in which the figures for average diameters and heights were combined with complete stem analyses of 10 dominant trees.

As indicated in this table, the periodic annual volume increment of spruce at 100 years exceeds 5 cubic feet, and at 300 years it is double this amount. The periodic annual growth continues greater than the mean annual for a long time after 300 years. At 100 years of age the volume of the entire stem without bark of dominant Sitka spruce trees approaches the high figure of 300 cubic feet, and at 200 and 300 years it exceeds 1,000 and 2,000 cubic feet respectively.

TABLE 8.—*Average diameter, height, and volume and average volume growth of dominant Sitka spruce trees in Oregon and Washington.*

Age.	Size.		Volume.		Annual volume growth.			
	D. o. b. at 15 ft.	Total height.	Entire stem without bark.	From stump height to top d. i. b. of 10 inches.	Periodic.	Mean.	Periodic.	Mean.
Years.	*Inches.*	*Feet.*	*Cu. ft.*	*Bd. ft.*	*Cu. ft.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*
20	2.0	31	3	....	0.15	0.15	....	....
40	9.5	70	22	....	.9	.5	....	....
60	15.7	104	87	260	3.2	1.4	....	4
80	20.5	132	175	670	4.4	2.2	20	8
100	24.4	154	279	1,230	5.2	2.8	28	12
120	28.1	173	400	1,960	6.0	3.3	36	16
140	31.5	188	538	2,760	6.9	3.8	40	20
160	34.7	200	690	3,690	7.6	4.3	46	23
180	37.7	210	859	4,640	8.4	4.8	47	25
200	40.6	218	1,036	5,660	8.8	5.2	51	28
220	43.4	224	1,219	6,720	9.2	5.5	53	30
240	46.2	228	1,417	7,800	9.9	5.9	54	32
260	48.8	232	1,617	8,940	10.0	6.2	57	34
280	51.4	234	1,818	10,040	10.0	6.5	55	36
300	54.2	236	2,020	11,170	10.1	6.7	56	37

YIELD.

The yield of Sitka spruce per acre in the virgin forest varies considerably with its representation as a species in the stand, with the density of stocking, and with the quality of site. Although available data are not sufficient to furnish yield tables for the wide range

of conditions which obtain in the virgin forest, it is possible to give an idea of what may be expected under average conditions. The number of trees and the yield per acre in Table 9 are based on the averaged and curved values of twelve sample plots from one-half to 5 acres in size. On six of these plots Sitka spruce made up 88 to 100 per cent of the stand by volume; on five of them it made up 50 to 82 per cent, and on one plot it comprised 25 per cent. The plots were in essentially even-aged stands, except that the older stands contained an underwood of younger hemlock and cedar trees.

TABLE 9.—*Average yield per acre of stands of Sitka spruce and associated species on good quality sites in Oregon and Washington.*

(Curved.)

Age.	Trees per acre.	Yield per acre.	Mean annual growth.	Age.	Trees per acre.	Yield per acre.	Mean annual growth.
Years		*Board feet*	*Board feet*	*Years*		*Board feet*	*Board feet*
40	400	29,500	734	180	82	140,000	778
60	280	54,250	904	200	70	144,750	724
80	220	78,000	975	220	60	148,250	674
100	175	99,500	995	240	50	151,000	629
120	130	115,000	958	260	42	153,000	588
140	112	126,000	900	280	36	154,250	551
160	94	134,000	838	300	30	155,500	518

As represented by the figures in this table, the yield of spruce stands compares well with that of Douglas fir on the best sites. Up to 90 years it makes a better yield, at 100 years it equals, and thereafter it falls a little behind Douglas fir.[16] The yields of the table are those of the virgin forest; if proper methods of forest management were employed, and if the trees were thinned at regular intervals, these yields would be considerably increased. The rapid increment of Sitka spruce is especially evident when the periodic annual growth is considered, which between the ages of 40 and 60 years is 1,237 board feet.

MANAGEMENT.

Since Sitka spruce does not ordinarily grow in pure stands, but rather in intimate mixture with several other commercial trees, the principle of management which must be applied to spruce should be equally applicable to its associates—fir, hemlock, and cedar. The entire forest of which Sitka spruce forms a part must be treated uniformly. Hence the discussion of the management of spruce is interwoven with considerations of the other trees in the stand.

It has been shown that Sitka spruce is a very excellent timber tree, that its wood is superior to that of all others in the region for certain

[16] Manuscript report by E. J. Hanzlik, Forest Service, Mar. 14, 1912.

purposes, that the tree has habits of growth and hardiness that recommend it as a tree for the forester to favor and propagate for the forests of the future. It should be the objective, therefore, of timbermen and foresters so to manage spruce lands that they may become reforested through natural seeding, and that the new crop may contain a desirable admixture of Sitka spruce wherever this species will thrive.

Much of the land upon which the virgin forests of spruce occur has agricultural value and will be put to that use after the removal of the timber. On such lands no effort need be made by the forester or lumberman to promote a new crop to take the place of the one removed, but on all other lands this should be done.

The rapid extension of logging operations in this type makes very timely a discussion of methods of forest management which will insure continuous crops of timber.

OWNERSHIP.

The present ownership of the commercial Sitka spruce is shown in Table 10.

TABLE 10.—*Ownership of Sitka spruce timber, by classes of owners, in millions of feet, board measure.*

Ownership.	Washington.	Oregon.	California.	Alaska.	British Columbia.
Federal[1]	1,550	300	(2)	15,000–18,000	
State	720	(2)	(2)		1,423
Private	4,205	4,074	187	(2)	12,742
Total	6,475	4,374	187	15,000–18,000	14,165

[1] Including Indian reservation. [2] Negligible amount.

From the above it is seen that in Alaska the Sitka spruce forests are practically all under Federal control, but that in Washington, Oregon, and California the bulk of this timber is in private ownership. The perpetuation of forests of Sitka spruce and their future welfare are largely in the hands of private owners and not under the jurisdiction of public agencies of government. Many of the holdings have been consolidated into units of 1,000 to 30,000 acres, though small properties are not uncommon. The State lands of Washington are in various-sized blocks, which in the aggregate now amount to about 10,000 acres. The Sitka spruce timberlands under Federal control in Washington lie chiefly in the Olympic National Forest and

in the Quinault Indian Reservation. In Oregon they are confined to the Siuslaw National Forest and several military and lighthouse reservations.

FIRE PROTECTION.

The most important factor in the management of the Sitka spruce type is fire protection. Without effective fire protection all other steps in forest conservation are useless. The virgin forests of the Sitka spruce type in the coastal belt are perhaps less likely to suffer from fire than the Douglas fir forests of the Cascade Range, but they are by no means immune. Systematic organized fire protection during the two or three dry summer months is essential for the safety not only of the virgin forest but also of the new crop of reproduction which follows logging. In the course of lumbering, special precautions should be taken by operators to prevent the escape of fire, for an accidental and uncontrolled fire in dry slashings may gain such headway that it will do great damage to adjoining standing timber and especially to areas of second-growth timber on older cuttings.

METHOD OF CUTTING.

Clear cutting is the method of logging universally employed in the spruce region; it is the only method practicable in these dense forests of very large trees. Moreover, Sitka spruce and western hemlock when isolated by the removal of a part of the stand are so subject to windthrow that any method of reserving seed trees of these species or of making a selection cutting is technically undesirable. Steam logging, moreover, fits in well with the requirements of the species, except so far as it increases the fire hazard, for it helps to expose the mineral soil.

SLASH DISPOSAL.

Slash disposal in the heavy forests of the Pacific coast region means the elimination of slash by broadcast burning. The objects are to reduce the fire hazard in the débris left after logging, to provide a proper seed bed for reproduction, and to retard the spread of insect and fungous diseases.

By far the most important of the above objects is to reduce the fire hazard. Since this is so the necessity for burning slash depends largely upon the fire menace of the region. Although in the spruce belt of Oregon and Washington the rainfall is abundant and fogs are frequent throughout most of the year, there are two months or more in the summer when slashings become dry, and uncontrollable fires may start and do untold damage. Because of this Sitka spruce slashings in this region should ordinarily be burned.

In Alaska, on the other hand, the danger of forest fires in the spruce belt is not great even in old cuttings because of frequent and heavy rains in the summer as well as throughout the rest of the year. Slash burning, therefore, is unnecessary and, moreover, highly undesirable, because it destroys the layer of humus and duff with which the rock is all too scantily covered in that thin-soiled country. Foresters recommend that in Alaska the slash be lopped and allowed to lie, and this is the required practice after logging on the national forests of the Territory.

If slash is to be burned in Sitka spruce stands, it is very important that it should be done the first spring or fall following logging, so that the crop of seedlings which springs up in the first growing season after cutting will not be killed by the fire. Slash burning should also be done at a time when the weather conditions are such that the fire can be held in control on the area which it is intended to burn. Further, the slash fire should be hot enough to clean up all the inflammable débris.

PROVISIONS FOR REPRODUCTION.

Studies of old cuttings indicate that Sitka spruce reproduction ordinarily follows the removal of the virgin forest, unless the area has been subjected to repeated fires. Reproduction is abundant where the slash has not been burned at all, as well as where there has been but one slash fire immediately after logging. Sitka spruce seems to be represented in the reproduction in as abundant proportions as it was in the original forest. It is apparent that this abundant reproduction following logging comes from seed which had accumulated in the ground before the virgin timber was cut, had escaped injury from fire (if the slashing was burned), and had germinated when the forest floor became exposed to the light and warmth of the sun's rays. Because of this adequate store of seed in the ground, special provisions for leaving spruce seed trees is not essential, provided only that the area is effectively safeguarded from fires after this seed germinates. As a precaution in case of an accidental fire, and as an added assurance of natural reproduction, it is well to leave occasional seed trees of such wind-firm associated species as Douglas fir, choosing those which are good seed producers. It is not ordinarily advisable to leave single seed trees of Sitka spruce, for they are too likely to be wind thrown. To secure some of this species in the next crop, reliance must be placed on the seed stored in the forest floor and released by the cutting of the virgin forest.

If natural reproduction does not restock an area adequately, it may occasionally be advisable in the interest of good management

to renew the forest artificially by seeding or by planting nursery-grown trees. This may be advisable if repeated fires have so denuded the land of seed trees and of reproduction arising from stored seed that there is no way for the natural regeneration of the stand to take place except by the slow process of migration from the surrounding timber. Methods of artificial reforestation of Sitka spruce are in general similar to those employed for Douglas fir. Occasionally successful results may be obtained from the direct sowing of seed on the denuded area, either broadcast or in specially prepared spots. This method, however, is very uncertain because of the likelihood of the seed being destroyed by birds or rodents and because of the heavy mortality which frequently occurs among the young seedlings during the first years after germination. Planting nursery-grown trees is a more dependable method, and while the initial expense may be greater than that of direct seeding, it may prove to be cheaper in the end. The use of 3-year-old transplant stock is recommended. On the better quality of sites Sitka spruce may be planted pure over relatively small areas; but, since it more commonly occurs associated with other species, a mixture of spruce with Douglas fir or hemlock is usually preferable. The composition of the former stand should largely govern the choice of species.

ROTATION.

A relatively short rotation is possible in Sitka spruce forests because of their rapid growth. Crops suitable for pulpwood might be produced on the best sites in 40 years or less, and crops for saw timber in twice that period. Information on the growth rate of the Alaskan forests is meager, but the indications are that a somewhat longer period will be required to produce timber suitable for various purposes than is needed in Oregon and Washington.

APPENDIX.

TABLE 11.—*Volume table for Sitka spruce in Oregon and Washington.*

This table is based on the measurement in 1914 and 1919 of 450 felled Sitka spruce (*Picea sitchensis*) trees, grown in fully stocked stands, averaged for all sites and seven localities at elevations from sea level to 1,200 feet, and from southern Oregon to northern Washington. Trees were scaled by Scribner Decimal C rule to a top diameter of 10 inches inside bark; actual height of stump was used (it averaged 8 feet); logs were scaled in 32-foot lengths and less, plus an allowance of 0.5 foot for trimming. The table was constructed by the frustum form factor method and volumes curved. Trees are classified according to their diameter outside bark at 1 foot above pronounced basal swell, which was found to average 8 feet above ground. No allowance is made for defect or breakage. Breakage in 184 trees amounted to less than 2 per cent of merchantable volume.

Diameter above swell.	Average.[1]	Number of 32-foot logs.												Basis.
		2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	
		Total height in feet.												
		112	128	142	158	173	188	202	217	231	241			
		Volume in board feet in tens.												
Inches.														*No. trees.*
12	5	26	......	......	......	......	......	......	......	......	......	......	......	......
14	12	28	......	......	......	......	......	......	......	......	......	......	......	......
16	19	30	41	......	......	......	......	......	......	......	......	......	......	..
18	26	34	46	59	......	......	......	......	......	......	......	......	......	..
20	40	39	53	69	83	......	......	......	......	......	......	......	......	3
22	58	45	60	79	96	111	......	......	......	......	......	......	......	14
24	83	51	69	90	109	129	......	......	......	......	......	......	......	14
26	108	56	78	102	123	147	172	198	......	......	......	......	......	24
28	140	......	88	115	139	167	195	226	255	......	......	......	......	23
30	178	......	98	130	158	188	220	254	287	......	......	......	......	27
32	219	......	110	144	175	210	246	283	321	358	......	......	......	31
34	269	......	123	158	195	234	273	314	355	406	......	......	......	24
36	317	......	......	174	215	258	302	346	382	437	......	......	......	30
38	374	......	......	191	237	283	330	379	430	479	......	......	......	25
40	431	......	......	208	259	310	362	415	469	523	......	......	......	31
42	493	......	......	224	283	338	394	452	511	570	......	......	......	25
44	558	......	......	239	309	369	429	491	554	619	686	......	......	13
46	622	......	......	255	335	400	464	532	601	671	742	......	......	26
48	692	......	......	......	364	433	502	576	650	726	802	881	......	20
50	768	......	......	......	395	466	542	622	702	783	866	951	......	19
52	842	......	......	......	......	503	584	668	755	842	932	1,022	......	18
54	916	......	......	......	......	538	626	718	810	904	999	1,096	......	13
56	998	......	......	......	......	......	673	769	868	968	1,069	1,173	1,278	10
58	1,081	......	......	......	......	......	718	821	926	1,034	1,147	1,253	1,366	8
60	1,169	......	......	......	......	......	764	875	988	1,102	1,220	1,331	1,455	5
62	1,250	......	......	......	......	......	811	930	1,051	1,172	1,295	1,418	1,545	7
64	1,334	......	......	......	......	......	860	987	1,115	1,246	1,373	1,505	1,638	4
66	1,423	......	......	......	......	......	911	1,045	1,182	1,320	1,454	1,597	1,734	7
68	1,514	......	......	......	......	......	......	1,107	1,252	1,397	1,539	1,690	1,833	10
70	1,609	......	......	......	......	......	......	1,168	1,323	1,474	1,630	1,786	1,933	4
75	1,862	......	......	......	......	......	......	......	1,509	1,680	1,862	2,037	2,199	7
80	2,126	......	......	......	......	......	......	......	1,707	1,904	2,102	2,301	2,495	4
85	2,412	......	......	......	......	......	......	......	......	2,148	2,374	2,586	2,814	2
90	2,714	......	......	......	......	......	......	......	......	2,424	2,656	2,891	3,139	2
														450

[1] When trees are not tallied by number of logs, use this column.

TABLE 12.—*Volume table for Sitka spruce in Behm Canal (Alaska) region.*

This table is based on taper measurements, in 1917, of 131 trees, total height and length of tip of 28 trees, and total height only of 92 trees which grew near Loring, Alaska. Figures indicate merchantable volumes, scaled by Scribner Decimal C rule, and represent contents from stump height of 2 feet and up to 6 inches d. i. b. at top. They are unreliable for trees over 44 inches in diameter. The table was prepared under the direction of R. E. Kan Smith.

Diameter breast-high.	Volume.	Diameter breast-high.	Volume.
Inches.	*Board feet in tens.*	*Inches.*	*Board feet in tens.*
24	82	46	400
26	101	48	445
28	132	50	491
30	154	52	536
32	166	54	587
34	192	56	639
36	219	58	686
38	250	60	736
40	283	62	784
42	318	64	837
44	357	66	890

TABLE 13.—*Log volume table for Sitka spruce in Oregon and Washington.*

This table was constructed from measurements of 234 felled Sitka spruce trees in Oregon and Washington (the majority of which grew along the Humptulips River in Washington). By means of the Scribner Decimal C rule the volume of each log and its percentage of the total merchantable volume in the tree were calculated, and these percentages were curved and applied to the merchantable volume of the average tree for each diameter class. Logs are in 32-foot lengths.

Diameter above swell.	Total merchantable volume.	Log volume and percentage of total volume.								Basis.
		Butt log.		Second log.		Third log.		Fourth log.		
Inches.	*Bd. ft. in tens.*	*Bd. ft. in tens.*	*Per cent.*	*Bd. ft. in tens.*	*Per cent.*	*Bd. ft. in tens.*	*Per cent.*	*Bd. ft. in tens.*	*Per cent.*	*No. trees.*
20	40	23	57.8	13	33.7	....	....	....	....	2
22	58	32	54.9	18	32.5	....	....	....	....	9
24	83	43	52.2	26	31.6	....	....	....	....	9
26	108	53	49.6	33	30.8	....	....	....	....	10
28	140	66	47.1	42	30.3	....	....	....	....	8
30	178	79	44.6	53	29.8	34	19.4	....	....	14
32	219	93	42.6	64	29.4	42	19.5	....	....	0
34	269	109	40.7	78	29.0	53	19.6	....	....	23
36	317	125	39.4	91	28.7	62	19.7	35	11.0	28
38	374	143	38.3	106	28.5	74	19.8	41	11.0	0
40	431	161	37.5	122	28.3	86	19.9	47	11.1	35
42	493	181	36.8	138	28.1	98	19.9	55	11.2	0
44	558	202	37.3	156	28.0	112	20.0	63	11.3	32
46	622	222	35.8	173	27.9	124	20.0	71	11.4	0
48	692	245	35.4	192	27.7	139	20.1	80	11.5	18
50	768	269	35.1	210	27.4	155	20.2	89	11.6	0
52	842	292	34.7	229	27.2	171	20.3	98	11.7	15
54	916	315	34.4	247	27.0	187	20.4	108	11.8	0
56	998	340	34.1	268	26.9	204	20.5	119	11.9	14
58	1,081	365	33.8	288	26.7	223	20.6	129	12.0	0
60	1,169	391	33.5	309	26.5	242	20.7	141	12.1	4
62	1,250	413	33.1	329	26.3	259	20.7	152	12.2	0
64	1,334	437	32.8	348	26.1	277	20.8	164	12.3	4
66	1,423	461	32.4	369	26.0	296	20.8	178	12.5	0
68	1,514	484	32.0	392	25.9	316	20.9	191	12.6	5
70	1,609	510	31.7	413	25.7	338	21.0	204	12.7	0
75	1,862	575	30.9	472	25.4	395	21.2	244	13.1	4
										234

TABLE 14.—*Comparative diameters at breast height and above swell of Sitka spruce, based on maximum taper.*

This table is based on maximum taper measurements of 37 trees which grew in Oregon and Washington. The figures under "taper" are inches per foot of vertical distance. The diameters above swell are noted for average heights of swell.

(Curved.)

Diameter breast-high.	Diameter above swell.	Average height of swell.	Taper.	Diameter breast-high.	Diameter above swell.	Average height of swell.	Taper.
Inches.	*Inches.*	*Feet.*	*Inches.*	*Inches.*	*Inches.*	*Feet.*	*Inches.*
60	51	7	3.5	110	76		4.5
65	56		3.5	115	80	12	4.6
70	61	7	3.6	120	85		4.7
75	66		3.7	125	89		4.8
80	67		3.8	130	93	12	4.9
85	71	8	3.9	135	97		5.0
90	76		4.0	140	102	12	5.1
95	72		4.1	145	106		5.2
100	77	10	4.2				
105	81		4.3				

TABLE 15.[1]—*Average total height of Sitka spruce on all sites in different parts of Oregon and Washington.*

(Curved.)

Age.	Tsiltcoos.	Newport.	Clatsop.	Raymond.	Hoquiam.	Beaver.	Average.
	Total height in feet.						
Years.							
20	22	20	48	32	28	38	31
30	44	34	66	52	48	60	51
40	62	51	82	70	66	85	70
50	82	70	96	85	83	110	87
60	100	89	109	98	99	130	104
70	118	106	122	110	114	147	119
80	134	121	133	120	127	161	132
90	148	134	144	130	141	173	144
100	158	147	155	139	154	183	154
110	168	157	165	148	166	192	164
120	176	167	173	156	176	201	173
130	184	175	181	164	186	209	181
140	190	183	188	171	194	216	188
150	196	190	194	178	201	222	194
160	200	196	199	184	205	227	200
170	205	201	204	190	213	232	205
180		205	208	196	218	236	210
190		210	212	201	223	240	214
200		213	215	206	227	244	218
210		216	217	210	230	246	221
220		218	220	214	234	249	224
230		220	222	218	236	251	226
240		222	223	221	239	252	228
250		224	225	223	241	254	230

[1] The following is a description of the localities in which the growth measurements were taken:

Tsiltcoos Lake, Lane County, Oreg.—Pure stand of even-aged second growth (175 years) on gentle slopes, at elevation of 150 to 300 feet. Soil deep, loose, sandy to sandy loam; moist but well drained.

Newport, Lincoln County, Oreg.—Three types; 130-year-old pure stand on moist, well-drained flat at 200-foot elevation in deep sandy loam; 320-year-old stand mixed with young hemlock on slopes, 300 to 350 feet above sea level in deep, well-drained sandy loam; and 300-year-old mixed stand in wet clay loam of creek bottom, 25 to 50 feet in elevation.

Clatsop, Clatsop County, Oreg.—Two types: 300-year-old pure stand on gentle slopes at altitudes of 900 to 1,100 feet, deep, moist, well-drained clay loam; 300-year-old stand in mixture with hemlock on level ground of wet clay loam at altitude of 400 feet.

Raymond, Pacific County, Wash.—Two types; small groups of even-age, varying between 110 and 440 years, on slopes of moderate pitch, well drained, deep, and of clay loam; parklike stand on poorly drained flat, at elevation of 250 to 300 feet.

Hoquiam, Grays Harbor County, Wash.—Two types; 250-year-old pure stand on moist, well-drained flat, at 400 feet elevation, in loamy soil underlain with gravel; 350-year-old stand in mixture on wet poorly drained flat, of clayey soil at same elevation.

Beaver, Clallam County, Wash.—Three hundred-year-old, pure stand in very moist, level, creek basin of rich alluvial soil at altitude of 600 feet.

TABLE 15.—*Average total height of Sitka spruce, etc.*—Continued.

Age.	Tsiltcoos.	Newport.	Clatsop.	Raymond.	Hoquiam.	Beaver.	Average.
	Total height in feet.						
Years—Continued.							
260	....	225	226	225	242	255	232
270	....	227	227	227	243	256	233
280	....	228	228	229	244	258	234
290	....	229	229	230	245	259	235
300	....	230	230	231	246	260	236
310	....	230	231	232	246	....	236
320	....	231	231	232	246	....	236
330	....	231	231	232	247	....	237
340	....	231	232	233	247	....	237
350	....	232	232	233	247	....	237
360	....	232	232	233	248	....	237
370	....	232	232	234	248	....	237
380	....	232	233	234	248	....	238
390	....	....	233	234	249	....	238
400	....	....	234	234	249	....	238
Basis: Number of measurements	220	189	220	311	138	182	1,260

TABLE 16.[1]—*Average diameter outside bark at 15 feet above ground of Sitka spruce on all sites in different parts of Oregon and Washington.*

(Curved.)

Age.	Tsiltcoos.	Newport.	Clatsop.	Raymond.	Hoquiam.	Beaver.	Average.
	Diameter in inches outside bark at 15 feet.						
Years.							
20	1.7	2.3	3.2	1.6	2.2	3.4	2.0
30	5.5	6.3	7.2	4.4	5.2	8.3	5.6
40	9.1	10.0	11.1	7.2	8.3	12.4	9.5
50	13.0	13.7	14.1	9.7	11.2	16.2	12.8
60	16.6	16.8	16.5	12.3	13.7	19.2	15.7
70	19.7	19.7	18.5	14.7	15.9	21.7	18.2
80	22.3	22.3	20.4	16.9	18.1	23.9	20.5
90	24.6	24.6	22.1	19.1	20.1	25.8	22.5
100	26.6	26.6	24.8	21.2	22.0	27.8	24.4
110	28.4	28.6	25.5	23.3	23.7	29.5	26.3
120	30.1	30.3	27.2	25.4	25.4	31.0	28.1
130	31.5	31.8	28.8	27.6	27.2	32.5	29.9
140	32.8	33.2	30.3	29.7	28.8	33.8	31.5
150	34.3	34.8	32.8	31.8	30.4	35.2	33.1
160	35.6	36.6	33.3	34.0	32.0	36.4	34.7
170	36.9	37.7	34.9	36.1	33.6	37.8	36.2
180	38.2	39.1	36.4	38.2	35.1	39.0	37.7
190	....	40.3	37.8	40.3	36.7	40.2	39.2
200	....	41.7	39.3	42.4	38.2	41.3	40.6
210	....	43.0	40.7	44.6	39.7	42.2	42.0
220	....	44.3	41.9	46.7	41.2	43.3	43.4
230	....	45.5	43.1	48.7	42.7	44.2	44.8
240	....	46.7	44.2	50.5	44.2	45.2	46.2
250	....	47.8	45.3	52.3	45.7	46.1	47.5
260	....	48.8	46.3	54.0	47.8	47.1	48.8
270	....	49.8	47.3	55.4	48.7	48.0	50.1
280	....	50.8	48.3	56.8	50.1	48.9	51.4
290	....	51.8	49.3	58.0	51.6	49.7	52.7
300	....	52.8	50.3	59.3	52.9	50.6	54.0

[1] For description of localities see footnote to Table 15.

TABLE 16.—*Average diameter outside bark at 15 feet above ground of Sitka spruce on all sites in different parts of Oregon and Washington*—Continued.

Age.	Tsiltcoos.	Newport.	Clatsop.	Raymond.	Hoquiam.	Beaver.	Average.
	Diameter in inches outside bark at 15 feet.						
Years—Continued.							
310	....	53.8	51.1	60.5	54.4	....	55.3
320	....	54.8	52.4	61.7	55.8	....	56.6
330	....	55.7	53.5	62.8	57.2	....	57.8
340	....	56.7	54.5	64.0	58.6	....	59.0
350	....	57.5	....	65.1	60.0	....	60.2
360	....	....	....	66.2	61.4	....	61.4
370	....	....	....	67.3	62.8	....	62.5
380	....	....	....	68.4	....	....	63.6
390	....	....	....	69.6	....	....	64.7
400	....	....	....	....	....	....	65.8
410	....	....	....	....	....	....	67.2
Basis: Number trees	95	78	100	133	73	78	557

TABLE 17.—*Results of tests on Sitka spruce wood from Washington, in green and air-dry condition, in the form of small clear pieces.*[1]

[From Table 1, U. S. Dept. Agr. Bull. 556.]

Mechanical property.	Green condition.	Air-dry condition.
Number of rings per inch	9	9
Summerwood (per cent)	24	24
Moisture content (per cent)	53	8.9
Specific gravity, based on volume and weight when oven-dry	.37	.38
Weight per cubic foot (pounds)	33	26
Shrinkage from green to oven-dry condition:		
Radial (per cent)	4.5	....
Tangential (per cent)	7.4	....
Static bending:		
Fiber stress at elastic limit (pounds per square inch)	3,000	7,200
Modulus of rupture (pounds per square inch)	5,500	11,200
Modulus of elasticity (1,000 pounds per square inch)	1,180	1,610
Work to maximum load [2] (inch pounds per cubic inch)	6.4	10.4
Compression parallel to grain:		
Maximum crushing strength (pounds per square inch)	2,600	5,770
Compression perpendicular to grain:		
Fiber stress at elastic limit (pounds per square inch)	330	1,010
Shearing strength parallel to grain (pounds per square inch)	780	1,210
Tension perpendicular to grain (pounds per square inch)	230	....
Hardness, side:		
Load required to embed 0.444-inch ball to one-half its diameter (pounds)	370	530

[1] Test specimens were 2 inches by 2 inches in section. Bending specimens were cut 30 inches long; others were shorter, depending on test.
[2] Work to maximum load represents the shock-absorbing ability of the wood.

LUMBER GRADES.

The following lumber grades are in use for different Sitka spruce products:[17]

Finish: B and Better.
Flooring: B and Better.
Ceiling: B and Better.
Stepping: B and Better.
Battens: B and Better.
Partition: B and Better.
Bevel siding: A, B, C.
Wagon-box sets: B and Better.
Boards and strips: Selected Common, No. 1 Common.

[17] For further information, see West Coast Lumberman's Association, "Rule 2: Standard Classification, Grading, and Dressing Rules for Douglas Fir, Sitka Spruce, Cedar, and Western Hemlock Products," January 22, 1922.

Dimension, plank, and small timbers: Selected Common, Common.
Lath: Standard Grade.
Turning squares: Standard Grade.
Molding stock: Standard Grade.
Panel stock: No. 1, No. 2.
Factory lumber: Select Factory, No. 1 Shop, No. 2 Shop, 1-inch Shop Common.
Car siding and roofing: B and Better.
Ladder stock: Special Grade.
Cut-up sash and door stock: No. 1, No. 2.
Piano posts: Special Grade.
Sounding-board stock: Special Grade.
Box lumber: No. 1, No. 2, No. 3.
Airplane stock: Special Grade.
Flitches: Special Grade.

LOG GRADES IN BRITISH COLUMBIA.[18]

SPRUCE, PINE, AND COTTONWOOD.

No. 1: Logs 12 feet and over in length, 30 inches in diameter and over, up to 32 feet long, 24 inches if over 32 feet long, reasonably straight, clear, free from such defects as would impair the value for clear lumber.

No. 2: Logs less than 14 inches in diameter and not over 24 feet long, or not less than 12 inches in diameter and over 24 feet long, sound, reasonably straight, free from rotten knots or bunch knots, and the grain straight enough to insure strength.

No. 3: Logs having visible defects, such as bad crooks, bad knots, or other defects that would lower the grade of lumber below merchantable.

Cull: Logs lower in grade than No. 3 will be classed as culls.

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[18] "Forests of British Columbia," by H. N. Whitford and R. D. Craig, p. 170, 1918.

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